VI. THE NORMATIVE ELECTROENCEPHALOGRAPHIC DATA REFERENCE LIBRARY

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The 200 subjects used in this study are volunteer flight personnel on active duty in the United States Air Force. Their ages range from 25 to 40 years with 80 percent being in the 30- to 35-year age group. A majority of the subjects are pilots, but a certain number of navigators and electronic warfare officers are also included in the group.

Before their arrival in Houston for the recording session, all subjects underwent an extensive medical and psychological evaluation at the School of Aviation Medicine, Brooks Air Force Base, Texas.

The physiological parameters recorded from each subject include 18 derivations of electroencephalogram (EEG), 2 derivations of electro-oculogram (EOG), electrocardiogram (ECG), electromyogram (EMG), skin temperature, respiration, finger plethysmogram, and galvanic skin response (GSR).

Figure 1 illustrates the positions of the EEG electrodes on the scalp. The circles contain placement designations used in the 10-20 system, such as C_4 indicating the right central electrode position. Standard positions are used with the exception of F_1 and F_2 which indicate

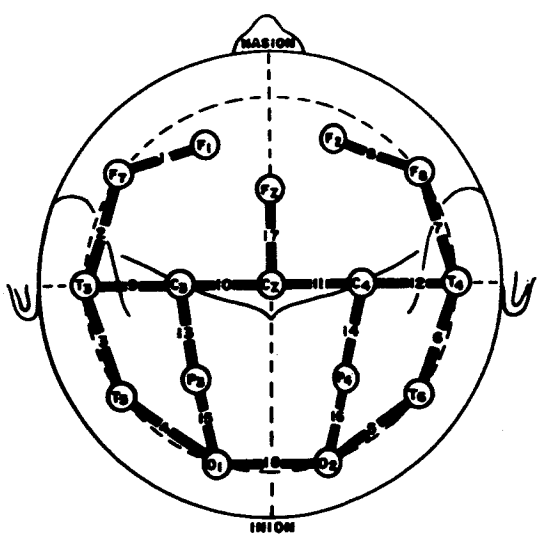

Figure 1. Positioning of EEG Electrodes on the Scalp

positions halfway between the area international F_{p1} and F_3 or F_{p2} and F_4 positions. The numbered lines connecting circles indicate derivations and channel numbers. Note that the montage used is exclusively bipolar and covers all major areas of the scalp.

The next 11 figures show the manner in which electrodes and transducers are attached to the subject. First, the head is measured for determination of each electrode placement according to the 10-20 system (fig. 2). Each site is scrubbed with a mixture of ether and acetone before placement of the electrode. The electrodes used are standard Grass Instrument silver cups anodized with chloride. Electrolyte paste is applied to the electrode site and to the concave surface of the electrode. Electrodes are fastened into place by gauze squares dipped in molten paraffin which clings firmly to the surrounding hair.

Figure 3 shows such electrodes in place. On non-hair-bearing areas, such as the frontal electrode sites, ordinary adhesive tape is used. The EOG electrode placements are illustrated in figure 4. These are located near the outer canthus of each eye for the horizontal component and above and below the left eye for the vertical component of the EOG.

Electrodes on the chest and arms are placed over sites prepared by the skin-drilling technique (figure 5). The skin site is lightly abraded with a high-speed dental burr which removes the outer keratinized layer of the epidermis so that a very low impedance is obtained. The system-ground electrode is placed on the left arm (fig. 5). ECG and impedance-pneumograph electrodes are applied to the chest over sites which are also prepared by the skin-drilling technique. Figure 6 shows the impedance-pneumograph electrodes placed on the anterior and posterior aspects of the right hemithorax. With this placement there is less cardiac artifact in the respiration signal, and primarily diaphragmatic respirations are

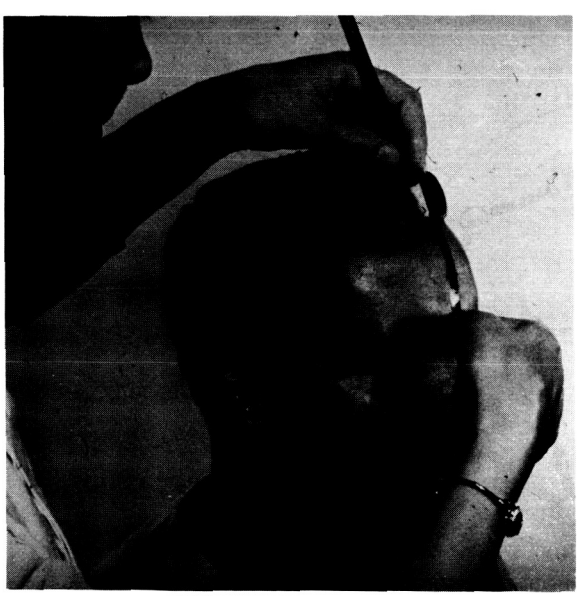

Figure 2. Measurement of the Head for Placement of Electrodes According to the 10-20 System

Figure 3. Placement of Electrodes Showing Use of Adhesive Tape on Non-Hair-Bearing Areas

recorded. The ECG electrodes are located bilaterally in the midaxillary lines. The right one is visible in figure 6; the left one is visible in figure 7.

The GSR electrode is placed over the palmar aspect of a finger on the left hand, the site being masked with tape to insure a constant area of 1 cm^2 (fig. 8). In figure 9 the silver-silver chloride pellet electrode for GSR is in place on the third finger. The thermistor for recording skin temperature is taped to digit four of the same hand. The transducer for the finger plethysmogram is placed over a nail bed on the same hand.

Figure 10 shows the recording chamber, a small electrically shielded room which is relatively sound deadened. The subject is seated in a comfortable reclining chair facing the stimulus-presentation box which contains a slide projector, a loud speaker, and a stroboscopic light. The electrodes are plugged into a rack (located behind the chair) which contains the primary signal conditioners. The subject's verbal responses are picked up by a microphone near the mouth. Certain responses are made by pressing buttons located on the right arm of the chair.

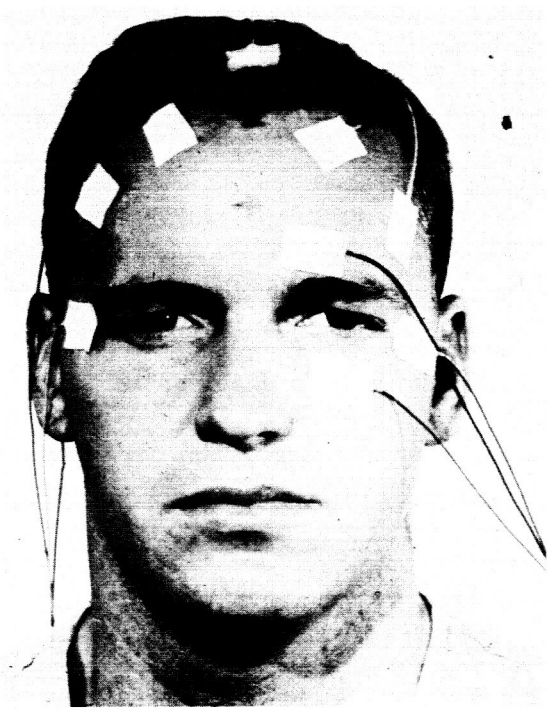

Figure 4. Electrode Placements for Horizontal and Vertical Components of the EOG (Showing Use of Adhesive Tape on Non-Hair-Bearing Areas)

Mechanical stimuli are delivered by means of a magnetic stimulator strapped to the left ankle of the subject (fig. 11). In figure 12 the primary signal conditioners located behind the chair are visible. The amplifiers are battery-operated solid-state modules having a gain of 1500. The amplified signals are led out of the room to the secondary amplifiers located in the apparatus room. Recordings are made on two 1-in. magnetic tapes running simultaneously as shown in figure 13. On one of the magnetic tape recorders, 12 EEG channels are recorded; on the second machine, 6 channels of EEG plus the other physiological parameters are recorded. Two channels of each magnetic tape contain identical technical data: a code channel and a channel containing voice and a steady 10 kc tone.

As the recording is being made, all of the signals are continuously monitored by means of an ink-writing oscillograph. The next two figures are examples of writeouts made during a recording session. In figure 14 the derivations of each channel are labeled. In the code channel at the bottom, down-going marks on the left indicate photic stimuli. Binary decimal code groups are used to designate the situation. For instance, code 013 at the right indicates that the subject was requested to clench his right hand in a fist. Following this, EMG activity is noted superimposed upon the respiration trace. Figure 15 is another example in which the Galvanic Skin Response (GSR) is written out instead of the ECG. Note that the subject had

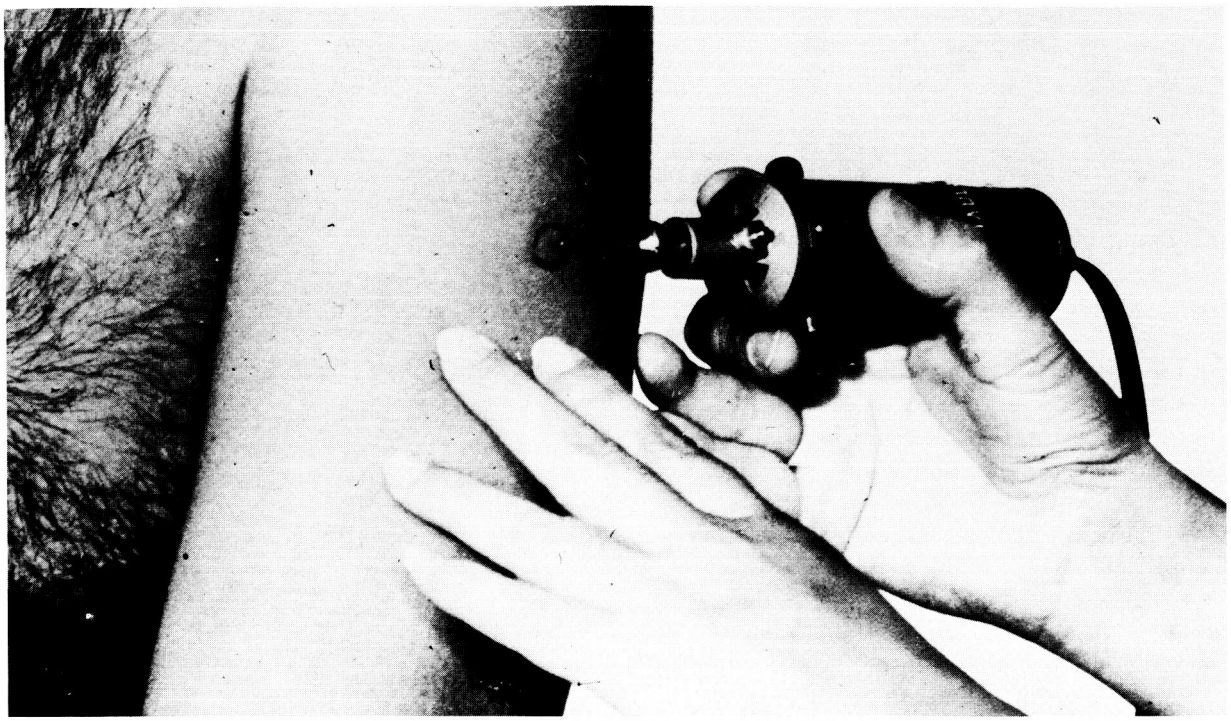

Figure 5. Skin-Drilling Technique for Placement of Electrodes on Chest and Arms

a GSR in response to the onset of mechanical stimulation. This is indicated by rapid downgoing pulses in the code channel on the left.

In figure 16 the rack of secondary signal conditioners and power amplifiers is shown on the right. Meters on the panel are for monitoring the levels of these parameters which are recorded dc, such as BSR, plethysmogram and skin temperature. The automatic program device is visible on the left. This unit was designed and built by the Space Biology Laboratory of U.C.L.A. The 1/4-in. program tape contains all verbal instructions for the subject, and it automatically presents stimuli and mental tasks in a given sequence which can be repeated for each subject with exactly the same timing.

The program was designed by a psychologist and is intended to create a spectrum of physiological and psychological situations ranging from rest and relative boredom through reception of sensory stimuli to solving increasingly difficult discriminative mental tasks.

The program begins with the subject in a resting condition, and preliminary recordings are made with the eyes both open and closed. After the subject receives the instructions recorded on the program tape, a series of sensory stimuli is administered. These consist of groups of photic, auditory and mechanical stimuli given at two different rates, 1 cps and 12 cps, both with the eyes open and with the eyes closed.

The subject is then asked to make some mental calculations, such as 21×45. He gives the answer into the microphone as soon as he has it.

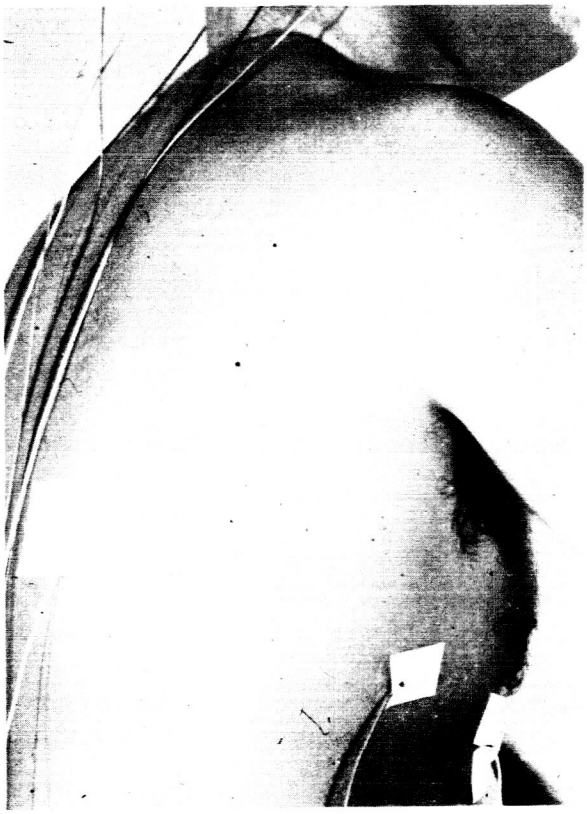

Figure 6. Impedance-Pneumograph Electrodes Placed on Anterior and Posterior Aspects of the Right Hemithorax; Right ECG Electrode Located Bilaterally on the Midaxillary Line

Figure 7. The Left ECG Electrode Located Bilaterally in the Midaxillary Line

Figure 8. GSR Electrode Placed over the Palmar Aspect of a Finger on the Left Hand

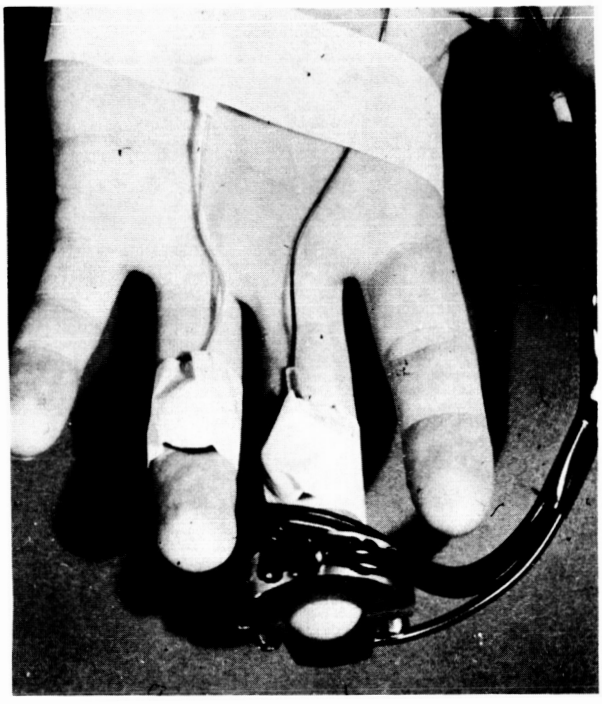

Figure 9. GSR Silver-Silver Chloride Pellet Electrode Placed on Third Finger of Left Hand

Figure 10. Recording Chamber Showing Subject Seated Facing Stimulus-Presentation Box

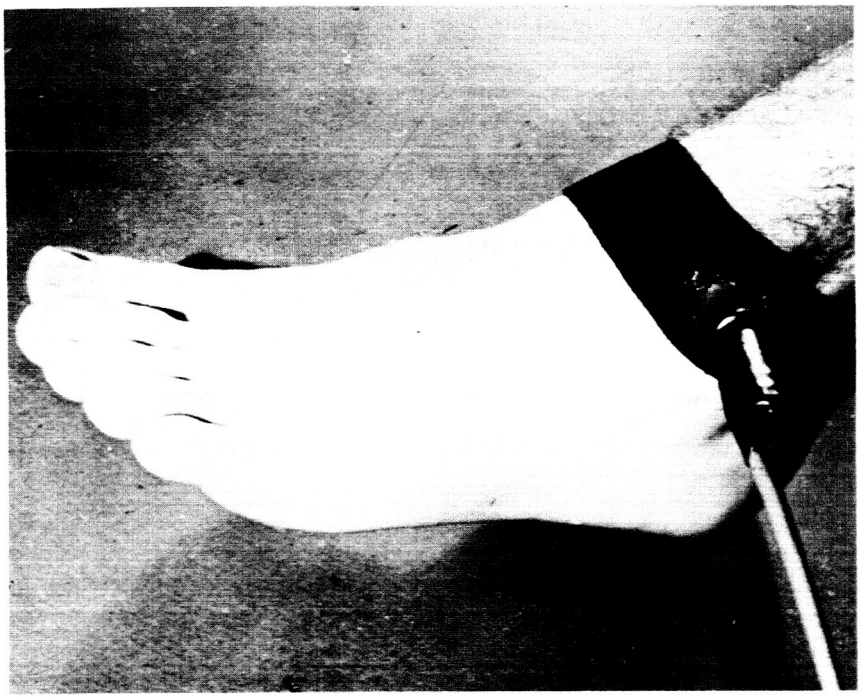

Figure 11. Magnetic Stimulator Strapped to Left Ankle

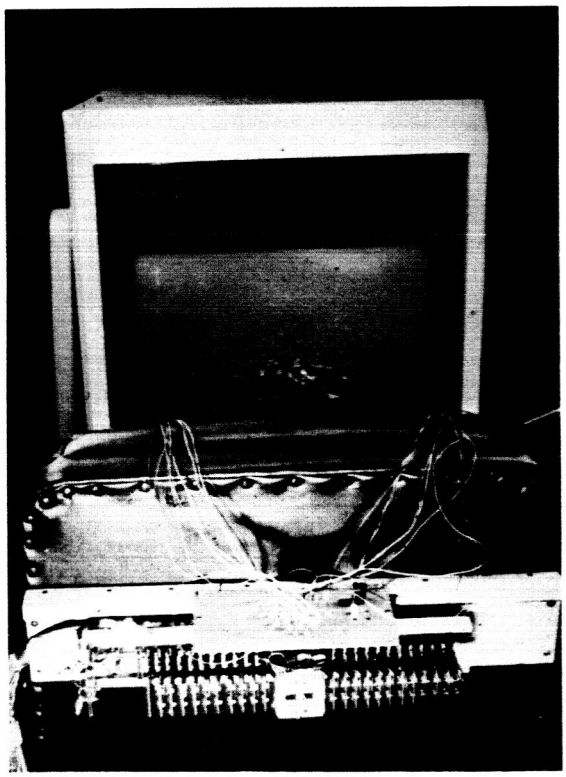

Figure 12. Primary Signal Conditioners Located Behind Chair

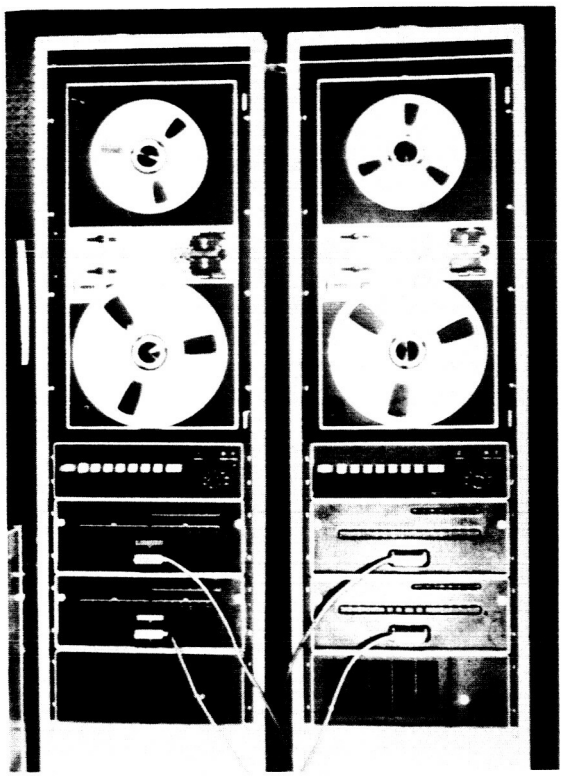

Figure 13. Simultaneously Running Magnetic Tape Recorders for Recording of EEG and other Physiological Parameters

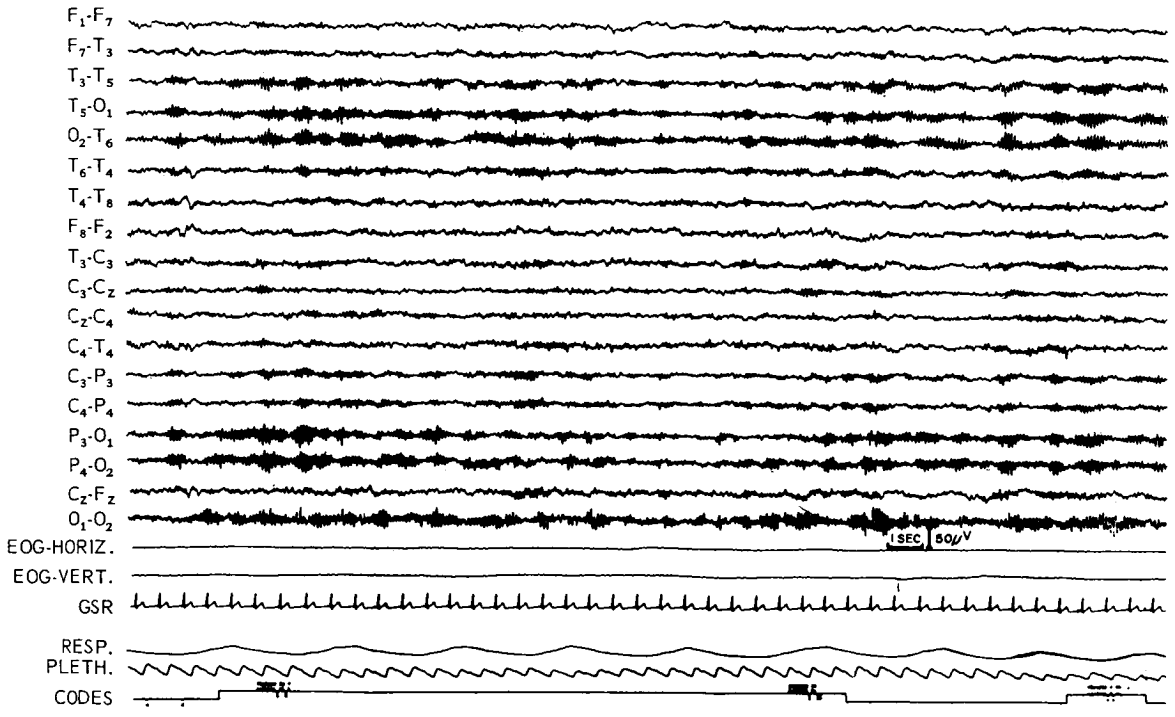

Figure 14. Writeout Made on Ink-Writing Oscillograph During a Recording Session (Showing ECG)

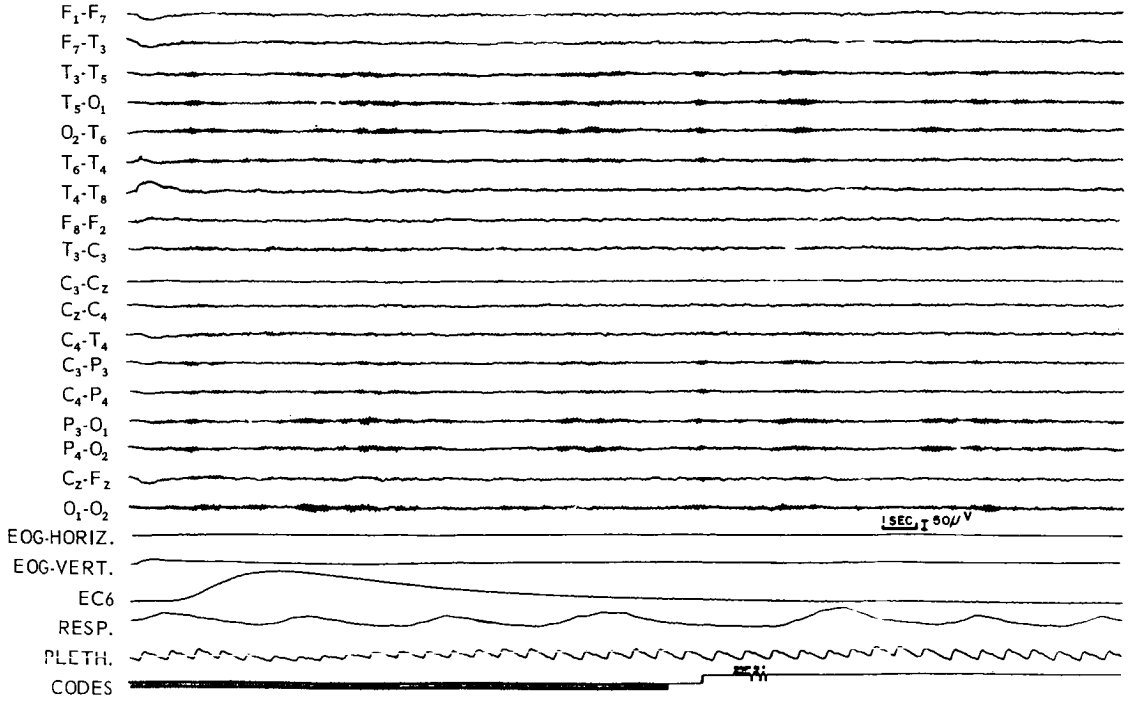

Figure 15. Writeout Made on Ink-Writing Oscillograph During a Recording Session (Showing GSR)

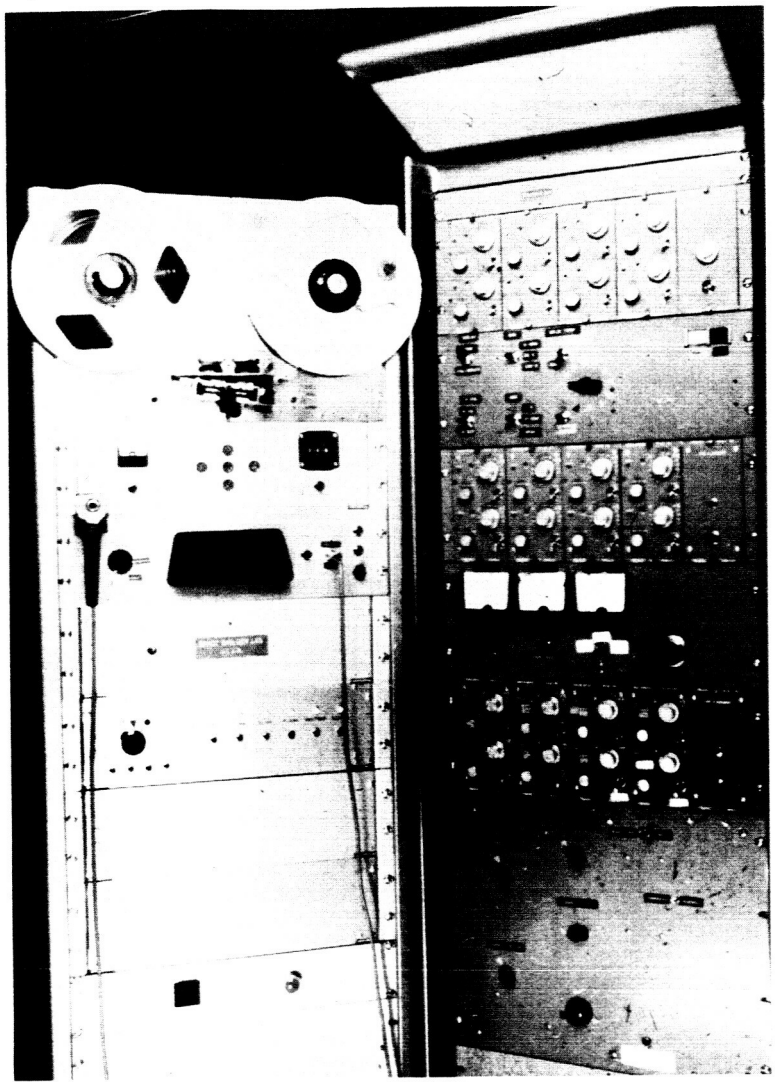

Figure 16. Rack of Secondary Signal Conditioners (right) and Automatic Program Device (left)

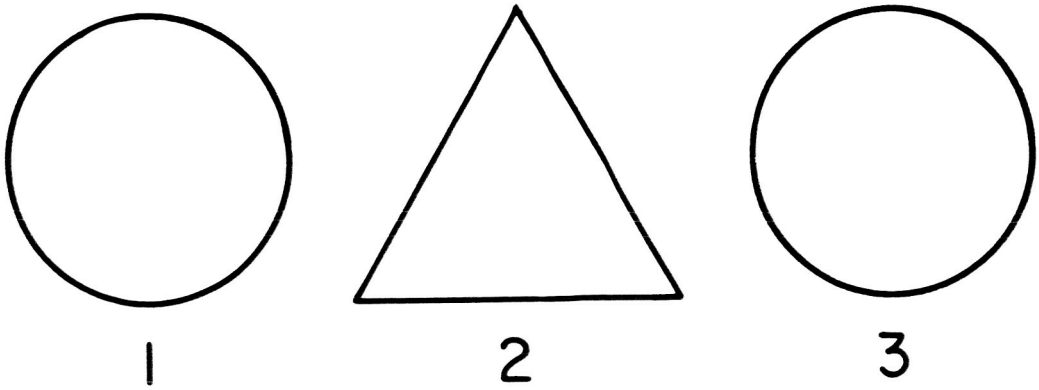

Figure 17. Example of Oddity Problems Presented on Screen to Subject at Unannounced Times Between Tasks

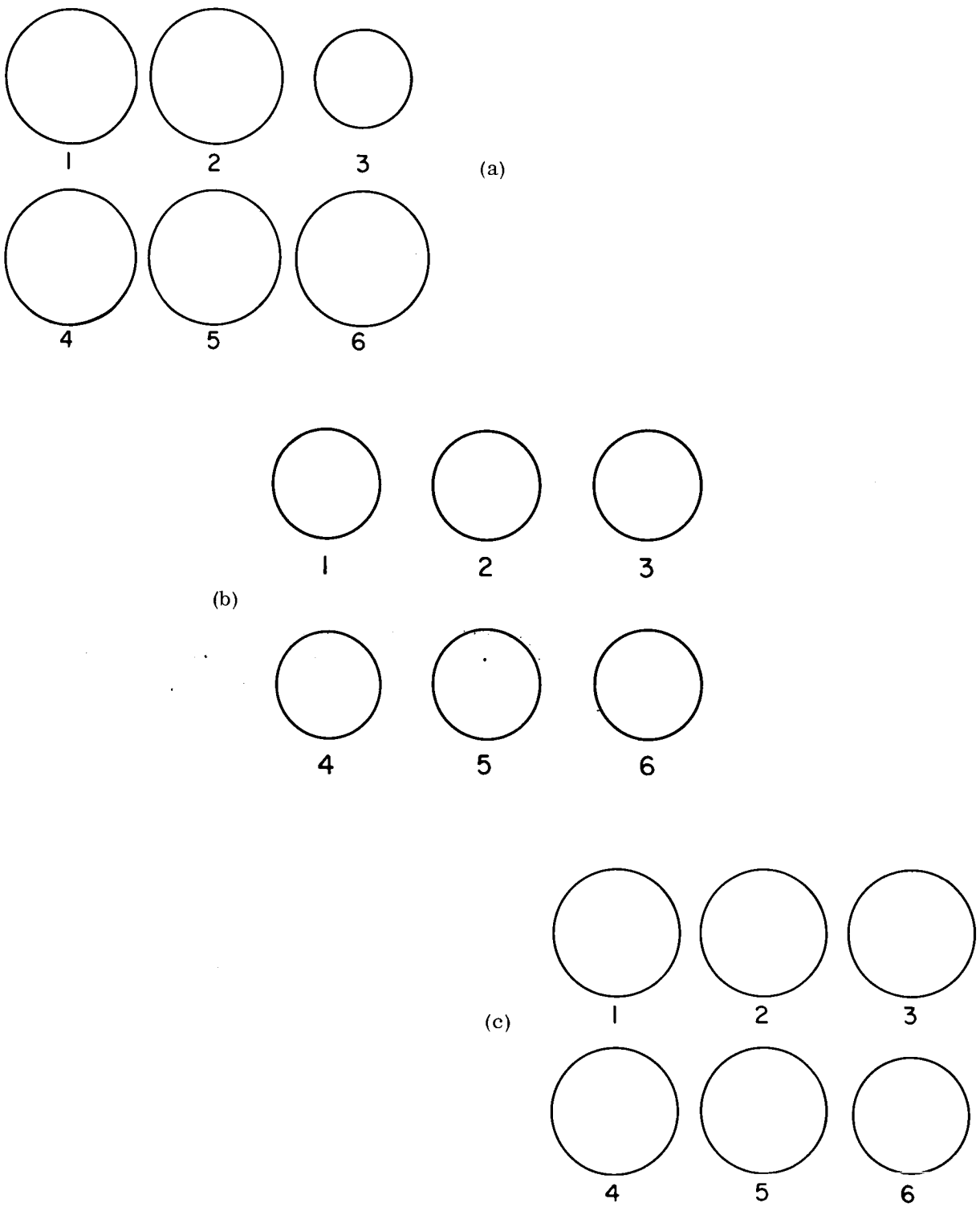

Figure 18. Examples of Increasingly Difficult Slide Series Presented to Subject for Size Differentiation

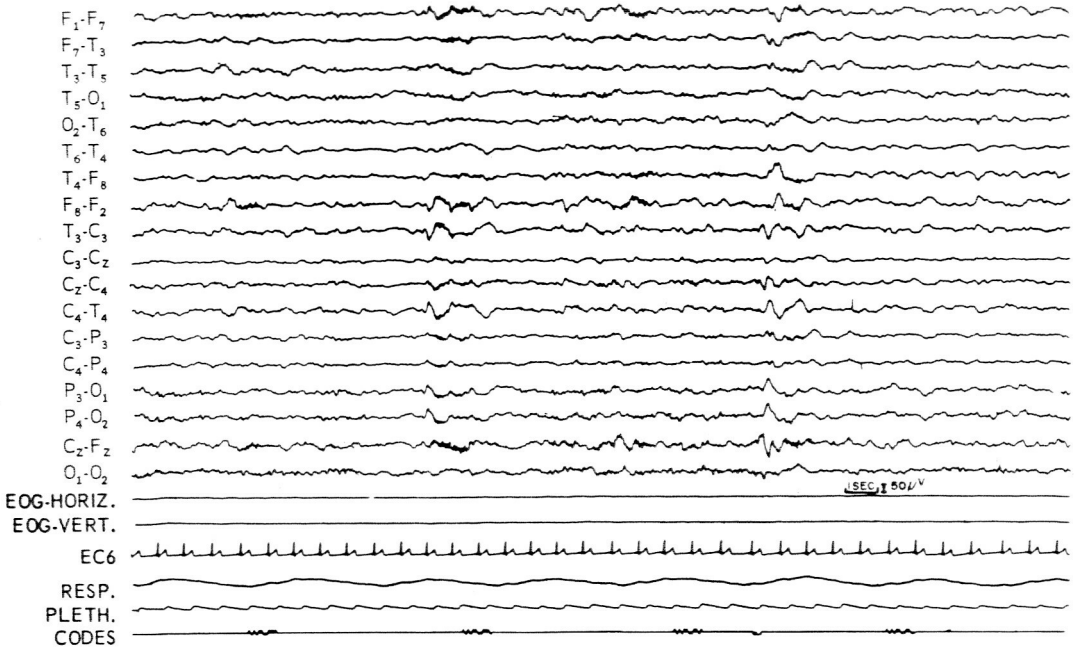

Figure 19. Writeout Made on Ink-Writing Oscillograph During Sleep

Figure 20. Setup for Location and Automatic Transfer of Selected Code Groups from Sleep Tape to Tape Made During Waking Portion of Program

Next he is given a long series of groups of three tones during which time he is to press a button after he hears the third tone of each group. Of 100 groups of three tones, two of the tone groups have an unusually long delay before the third tone.

At various unannounced times between the different tasks, oddity problems are presented on the screen before the subject. Such a problem is illustrated in figure 17. It consists of three figures, one of which is unlike the other two. The subject is instructed to press one of the three buttons lying under his right hand, which corresponds to the odd figure.

The last proportion of the waking record consists of a series of 60 slides containing six numbered circles such as illustrated in figure 18A. The subject is to say, into the microphone, which of the six circles is larger or smaller than the other five. If he cannot do this in the allotted time, or if he makes a mistake, a loud raspberry-type noise is sounded. The slides become more and more difficult, such as those illustrated in figure 18B and C, and the slides are presented at shorter and shorter intervals with less exposure time.

In order to complete the profile of each subject during various levels of consciousness, similar recordings are made while the subject lies on a bed and falls to sleep. Recordings are made during all levels of drowsiness and sleep. While the subject is asleep, mild auditory stimuli are administered, first below and then above the subject's arousal threshold.

Figure 19 is an example of a writeout made during sleep. The irregular down-going mark in the code channel indicates administration of a subthreshold auditory stimulus. Note that the codes are recorded every 6 seconds during sleep. After the sleep recording (usually containing 1 hour of data) is made, the writeout is inspected visually, and segments which illustrate typical predefined levels of sleep are selected for inclusion in the final recording. The code groups of the selected segments of the sleep recording are noted. The setup shown in figure 20 enables us to search the sleep tape for the selected code groups and automatically transfer the data in these segments to the end of the tape recording made during the waking portion of the program.

The final recording from each subject thus contains one hour of EEG and polygraphic data from each individual taken under a programed spectrum of levels of mental activity ranging from sleep through resting awake to solving of mental tasks.